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The status of butterflyfishes (Chaetodontidae) in the northern Persian Gulf, I.R. Iran

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ABSTRACT

1. Four species of Chaetodontidae, *Chaetodon melapterus*, *Chaetodon nigropunctatus, Chaetodon vagabundus* and *Heniochus acuminatus*, were observed in coral reef areas of the Iranian waters in the northern Persian Gulf.
2. *Chaetodon vagabundus* was very rarely observed.
3. Population size of the obligate corallivore *Chaetodon nigropunctatus* was found to be significantly correlated with percentage live coral cover, although results indicate more comprehensive surveys are needed before confirming *C. nigropunctatus* as an indicator species for changing conditions of coral reefs in the northern Persian Gulf.

KEY WORDS: butterflyfishes; Chaetodontidae; *Chaetodon melapterus*; *Chaetodon nigropunctatus*; *Chaetodon vagabundus*; coral; *Heniochus acuminatus*; indicator species; Iran; Persian Gulf

INTRODUCTION

The Chaetodontidae (butterflyfishes) comprise one of two major circumtropical reef-associated fish families, the other being Pomacanthidae (angelfishes). According to Allen *et al*. (1998), chaetodontids consist of 116 species and 10 genera of which 78% belong to the genus *Chaetodon* (Choat and Bellwood, 1991). Ninety per cent of the species occur in the Indo-Pacific region. The majority of butterflyfishes are brightly coloured, with some having eye bands or a dark spot on the posterior of the body. They are among the most important and valuable ornamental fish in the marine aquarium trade.

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In the wild, the diets of Chaetodontidae vary greatly among different genera. Approximately half of butterflyfish species feed on live coral polyps, while many others feed on cryptic reef invertebrates, sessile invertebrates or zooplankton (Roberts and Ormond, 1992). Algae are also a significant component of the diet of many species (Choat and Bellwood, 1991). The care of this group of fish in captivity is often difficult owing to the special feeding requirements (e.g. live coral polyps) of some species. As with most species of marine fish, sexual differences are not distinguishable and the breeding of these fish is extremely difficult in an aquarium (Choat and Bellwood, 1991).

Chaetodontids have been suggested as 'indicator organisms' of coral reef conditions, in that significant changes to their population levels and/or behavioural traits may be an indication of changing or stressful conditions on a coral reef (Reese, 1981; Crosby and Reese, 1996). Using data on butterflyfish assemblages on coral reefs of Reunion Island, Chabanet *et al.* (1997) found significant relationships between fish abundance and live coral cover, highlighting the importance of geomorphological zones and the degree of perturbation of the reef environment. They also demonstrated that the density of fish was largely limited by the percentage of live coral cover predominantly in disturbed sites. Cadoret *et al.* (1999) studied the abundance of butterflyfish on coral reefs of the Ryukyu Islands in southern Japan, and found the highest species richness and abundance of chaetodontid fish were on the reef slope and reef edge. They suggested that depth, substrate complexity and live coral cover influenced the distribution of chaetodontid fishes accounting for 20% of the variation in the species data matrix. Various studies have also indicated that benthic coverage by living scleractinian corals has a positive influence on the abundance of corallivore chaetodontids (Chabanet *et al.*, 1997; Öhman *et al.*, 1998; Zekeria and Videler, 2000). However, Zekeria and Videler (2000) found no significant correlation between the species richness of chaetodontids and coral coverage. Chabanet *et al.* (1997) found abundance of fish to be significantly correlated with the species diversity of corals in disturbed environments. Chabanet (2002) found significant differences in species richness and abundance of fish on fringing, inner and outer barrier reefs in Mayotte Island in the western Indian Ocean, and argued that the number of fish increased as depth increased. Patterns of coral fish assemblages have also been found to be dominantly determined by habitat characteristics (Chabanet, 2002; Garpe and Öhman, 2003). The conclusions from all of these studies have been that: (1) food availability seemed to be an important factor influencing distribution patterns of corallivore chaetodontid fishes; (2) the distribution of some chaetodontids may be influenced by depth gradient and substrate complexity; and (3) the abundance of corallivore butterflyfish is influenced by degree of environmental disturbance and stress of coral reefs.

The objective of this study was to conduct an initial investigation of butterflyfish species diversity, distribution and abundance, as well as their relationship to percentage live coral cover, in the northern Persian Gulf.

MATERIALS AND METHODS

Study area

The Persian Gulf is a semi-enclosed marginal sea surrounded by landmasses and located in the subtropical north-west of the Indian Ocean. The limited water exchange between the Persian Gulf and the Indian Ocean through the Straits of Hormuz results in relatively harsh conditions with regard to salinity, temperature and occasional extreme low tides which have an effect on marine organisms, especially coral reef communities. It is a very shallow sea with an average depth of about 35 m, and an average salinity and temperature of about 40 and 26°C (normally 14 to 34°C) respectively (Coles and Fadlallah, 1991). In recent years, coral bleaching has occurred throughout the world resulting in mass mortality of corals mainly due to the elevated temperature (Wilkinson, 2000). This has also been the case in the Persian Gulf over the last decade (Pilcher *et al*., 2000). Two mass mortality events of corals occurred in the northern part of the gulf mainly due to the high sea water temperature around Kish Island during 1996 and 1998 (Wilson *et al*., 2002).

There are 17 islands in the Iranian waters of the northern Persian Gulf that are surrounded by fringing coral reefs, and some scattered coral patch habitats existing in shallow areas along the shorelines of mainland Iran (Figure 1). Data for this study were collected from the coral reefs at Kish Island, Larak Island and Ni-Band Bay during the period 2000 to 2003. Coral reefs around the islands are of fringing type, while Ni-Band Bay corals are of patchy type stretched along the shoreline of the mainland. Larak Island is located in the Straits of Hormuz, therefore its corals are greatly influenced by the less saline and more nutrient-rich oceanic waters entering from the Indian Ocean. Conversely, coral reefs of Kish Island are located in the inner Persian Gulf area and therefore tolerate the more saline and less nutrient-rich

Figure 1. Study areas and coral reef distribution in the northern Persian Gulf, Iranian waters.

conditions more characteristic of nearly the entire gulf region. Ni-Band Bay coral reef patches are also located in the inner Persian Gulf, but are adjacent to a mainland embayment.

Sampling techniques

Butterflyfish population size and diversity were determined qualitatively by diver observations and quantitatively by transect survey (Hodgson *et al*., 2004). The presence and the abundance of each butterflyfish species, along with benthic substrate cover, were recorded for both shallow and intermediate transects. At each site, data were collected along four transects each 20 m long at shallow (3–6 m) and intermediate (8–12 m) depths. A belt transect method (5 m wide centred on each transect line) was used to estimate the abundance of butterflyfishes (Hodgson *et al*., 2004). A line–point intercept sampling method was used to study the nature of the substrate (Hodgson *et al*., 2004), with substrate type recorded at 0.5-m intervals along the transect. Substrate types were recorded as live coral, recently dead corals, coral rubble, fleshy seaweed, non-living bottom type (rock, sand and silt) and others (i.e. sponges and tunicates).

Data analysis

Differences between sites (including between a site sampled in different years) and at different depths were tested by two-factor ANOVA. A log-transformation was applied to data on abundance of butterflyfish to remove the heterogeneity of variances. Data on percentage of coral cover were arc-sin transformed. Student–Newman–Keuls (SNK) tests were used for *a posteriori* comparison among means. Time of sampling at each site was treated as the fixed factor for ANOVA comparisons, with depth of transect treated as a random factor and nested within a site. ANOVA analyses were performed using the GMAV5 (Underwood and Chapman, 1984). Spearman correlation and regression analyses were used to investigate the relationships between total number of butterflyfish and individual butterflyfish species per 400 m^2 with percentage of coral cover. Correlation and regression analyses were undertaken by using SPSS program version 12.0.

RESULTS

Butterflyfish diversity and distribution

The results of this study are in agreement with that of Hazaei (2000) and confirm the presence of four species of chaetodontids in the Iranian waters of the Persian Gulf: *Chaetodon melapterus* (Guichenot, 1862), the Arabian butterflyfish; *Chaetodon nigropunctatus* (Sauvage, 1880), (also referred to by some authors, e.g. Carpenter *et al*. (1997), as *Chaetodon obscurus* (Boulenger,1888)), the black spotted butterflyfish; *Chaetodon vagabundus* (Linnaeus, 1758), the vagabond butterflyfish; and *Heniochus acuminatus* (Linnaeus, 1758), the pennant coral fish. Three butterflyfish species were observed within belt transect areas: *C. melapterus*, *C. nigropunctatus* and *H. acuminatus*; *C. vagabundus* was noted only rarely and not within the belt transect areas. The mean and standard error of butterflyfishes within belt transect areas, as well as percentage cover of substrate types, are presented in Table 1. At all sites and depths, *C. nigropunctatus* was the most abundant species, followed by *C. melapterus*.

Butterflyfish abundance and substrata type

The occurrence of *C. nigropunctatus* and *C. melapterus* was always in association with coral formations. However, correlation analyses of butterflyfish with percent coral cover yielded mixed results (Table 2). *C. nigropunctatus* demonstrated a significant positive relationship with coral cover in shallow water transects collected in 2000 for Ni-Band Bay ($r = 0.95$; $p < 0.05$), and for pooled data from Larak Island

Table 1. Abundance of butterflyfish (individuals per 400 m^2) and percentage cover of substrate type parameters (other substrate = sponge, tunicate, etc.; non-living bottom = rock, sand, silt) in the study areas. Mean, standard error (SE) and number of transects (n) are provided

	Kish Island 2001		Kish Island 2002		Ni-Band Bay 2000		Ni-Band Bay 2003		Larak Island 2002	
	Shallow transect	Intermediate transect	Shallow transect	Intermediate transect	Shallow transect	Intermediate transect	Shallow transect	Intermediate transect	Shallow transect	Intermediate transect
Chaetodon nigropunctatus	Mean = 0.00 SE = 0.00 n = 4	Mean = 1.00 SE = 0.58 n = 4	Mean = 0.50 SE = 0.29 n = 4	Mean = 1.00 SE = 0.58 n = 4	Mean = 4.50 SE = 0.65 n = 4	Mean = 3.75 SE = 1.38 n = 4	Mean = 1.00 SE = 0.71 n = 4	Mean = 2.50 SE = 1.32 n = 4	Mean = 14.50 SE = 4.59 n = 4	Mean = 0.00 SE = 0.00 n = 4
Chaetodon melapterus	Mean = 0.00 SE = 0.00 n = 4	Mean = 1.00 SE = 1.00 n = 4	Mean = 0.25 SE = 0.25 n = 4	Mean = 0.00 SE = 0.00 n = 4	Mean = 0.00 SE = 0.00 n = 4	Mean = 0.00 SE = 0.00 n = 4	Mean = 0.00 SE = 0.00 n = 4	Mean = 0.00 SE = 0.00 n = 4	Mean = 0.50 SE = 0.50 n = 4	Mean = 0.00 SE = 0.00 n = 4
Heniochus acuminatus	Mean = 0.00 SE = 0.00 n = 4	Mean = 0.00 SE = 0.00 n = 4	Mean = 0.00 SE = 0.00 n = 4	Mean = 1.00 SE = 1.00 n = 4	Mean = 0.00 SE = 0.00 n = 4	Mean = 0.00 SE = 0.00 n = 4	Mean = 0.00 SE = 0.00 n = 4	Mean = 0.00 SE = 0.00 n = 4	Mean = 0.00 SE = 0.00 n = 4	Mean = 0.00 SE = 0.00 n = 4
Live coral	Mean = 21.25 SE = 1.61 n = 4	Mean = 13.12 SE = 1.57 n = 4	Mean = 15.00 SE = 3.54 n = 4	Mean = 8.13 SE = 2.58 n = 4	Mean = 26.25 SE = 4.15 n = 4	Mean = 28.13 SE = 8.92 n = 4	Mean = 30.00 SE = 3.06 n = 4	Mean = 28.13 SE = 7.93 n = 4	Mean = 42.50 SE = 13.50 n = 4	Mean = 2.50 SE = 1.02 n = 4
Recently dead coral	Mean = 0.00 SE = 0.00 n = 4	Mean = 0.00 SE = 0.00 n = 4	Mean = 0.00 SE = 0.00 n = 4	Mean = 1.25 SE = 0.72 n = 4	Mean = 3.75 SE = 2.98 n = 4	Mean = 1.87 SE = 1.20 n = 4	Mean = 1.87 SE = 1.20 n = 4	Mean = 0.63 SE = 0.63 n = 4	Mean = 0.63 SE = 0.63 n = 4	Mean = 0.00 SE = 0.00 n = 4
Coral rubble	Mean = 17.50 SE = 3.95 n = 4	Mean = 34.38 SE = 10.67 n = 4	Mean = 3.12 SE = 2.37 n = 4	Mean = 40.62 SE = 1.20 n = 4	Mean = 15.63 SE = 5.44 n = 4	Mean = 0.63 SE = 0.63 n = 4	Mean = 22.50 SE = 5.30 n = 4	Mean = 3.12 SE = 1.20 n = 4	Mean = 15.62 SE = 5.90 n = 4	Mean = 1.87 SE = 1.88 n = 4
Fleshy seaweed	Mean = 7.50 SE = 1.02 n = 4	Mean = 9.37 SE = 4.13 n = 4	Mean = 3.75 SE = 0.72 n = 4	Mean = 3.75 SE = 0.72 n = 4	Mean = 11.87 SE = 2.13 n = 4	Mean = 30.00 SE = 13.15 n = 4	Mean = 0.63 SE = 0.63 n = 4	Mean = 1.87 SE = 0.63 n = 4	Mean = 9.38 SE = 6.07 n = 4	Mean = 2.50 SE = 1.77 n = 4
Other substrate	Mean = 3.13 SE = 1.20 n = 4	Mean = 11.88 SE = 1.88 n = 4	Mean = 7.50 SE = 2.04 n = 4	Mean = 6.25 SE = 1.61 n = 4	Mean = 0.62 SE = 0.63 n = 4	Mean = 5.00 SE = 2.28 n = 4	Mean = 1.25 SE = 1.25 n = 4	Mean = 16.25 SE = 2.60 n = 4	Mean = 4.38 SE = 2.95 n = 4	Mean = 5.63 SE = 2.37 n = 4
Non-living bottom	Mean = 50.62 SE = 4.93 n = 4	Mean = 31.25 SE = 8.57 n = 4	Mean = 70.63 SE = 4.38 n = 4	Mean = 40.00 SE = 1.77 n = 4	Mean = 41.88 SE = 3.73 n = 4	Mean = 34.37 SE = 11.24 n = 4	Mean = 43.75 SE = 9.04 n = 4	Mean = 50.00 SE = 8.42 n = 4	Mean = 27.5 SE = 9.19 n = 4	Mean = 87.50 SE = 6.69 n = 4

Table 2. Spearman correlation matrix (with correlation coefficients and 2-tail p-values where significant; n.s. = not significant) for individual butterflyfish species with percentage coral cover. No values were calculated if a species of butterflyfish was not observed for a set of transects. Overall pooled = combined data of all sites, times and depths

	Kish 2001	Kish 2002	Ni-Band Bay 2000	Ni-Band Bay 2003	Larak 2002	Overall pooled
Chaetodon nigropunctatus	−0.701 n.s.	0.22 n.s.	0.52 n.s.	−0.49 n.s.	0.89 $p = 0.003$	0.39 $p = 0.01$
Chaetodon melapterus	−0.334 n.s.	0.33 n.s.	—	—	0.42 n.s.	0.06 n.s.
Heniochus acuminatus	—	0.33 n.s.	—	—	—	−0.05 n.s.

	Kish 2001		Kish 2002		Ni-Band Bay 2000		Ni-Band Bay 2003		Larak 2002	
	Shallow transect	Intermediate transect	Shallow transect	Intermediate transect	Shallow transect	Intermediate transect	Shallow transect	Intermediate transect	Shallow transect	Intermediate transect
Chaetodon nigropunctatus	—	−0.71 n.s.	−0.24 n.s.	0.71 n.s.	0.95 $p < 0.05$	0.20 n.s.	0.78 n.s.	−0.40 n.s.	0.60 n.s.	—
Chaetodon melapterus	—	0.00 n.s.	0.27 n.s.	—	—	—	—	—	0.26 n.s.	—
Heniochus acuminatus	—	—	—	0.82 n.s.	—	—	—	—	—	—

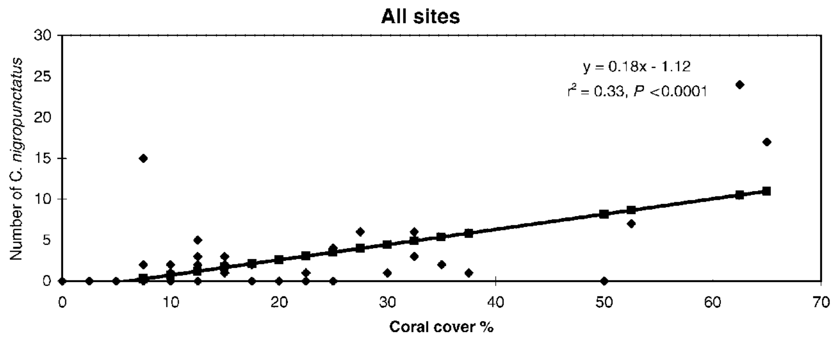

Figure 2. Regression equation and best-fit line for the relationship between *Chaetodon nigropunctatus* with coral cover based on pooled data of all transects from all sites, dates and depths.

($r = 0.893$; $p = 0.003$). No other species demonstrated a significant relationship with coral cover in either the shallow or intermediate transects, or pooled data, from any site. However, *C. nigropunctatus* exhibited relatively high correlation coefficients for Kish Island 2001 pooled data ($r = -0.79$) and 2002 intermediate depth transects ($r = 0.71$), and for Ni-Band Bay 2000 pooled ($r = 0.52$) and shallow depth transects ($r = 0.95$). When all transect data from all sites, times and depths are pooled and analysed, *C. nigropunctatus* was significantly correlated with coral cover ($r = 0.39$; $p = 0.01$). Regression analysis (Figure 2) of *C. nigropunctatus* with coral cover was significantly ($p < 0.0001$) correlated and explained one-third of the variability of *C. nigropunctatus* abundance ($r^2 = 0.33$).

Temporal and spatial variations in butterflyfish abundance

The results of two-factor ANOVA between sites for abundance of *C. melapterus*, *C. nigropunctatus* and coral cover yielded no significant differences between any sites (including between sampling years for a given site).

Within site comparisons between depths yielded significantly greater coral cover ($p < 0.01$) for shallow depth transects in Larak Island, significantly greater abundance of *C. melapterus* ($p < 0.05$) for shallow depth transects in 2002 at Kish Island, and significantly greater abundance of *H. acuminatus* ($p < 0.05$) for intermediate depth transects in 2002 at Kish Island. It should be noted that *H. acuminatus* was only sighted within the belt transects at the intermediate depths in 2002 at Kish Island.

DISCUSSION

An indirect effect of coral bleaching events in 1996 and 1998 in the northern Persian Gulf may be influencing the observed abundance of butterflyfish at Kish Island. Results of the current study may be seen to indicate that the decline in coral cover at Kish Island, mainly due to the mortality of branching corals of the genus *Acropora* (M. Shokri and S. Fatemi, pers. obs.), had a negative impact on abundance of *C. nigropunctatus* at this site when compared to Larak Island which did not experience severe coral bleaching. Adjeroud *et al.* (2002) reported on the relationship between temporal variation of butterflyfish and the corals as the only taxon directly affected by natural disturbances. They argued that the decrease in the density of corallivorous chaetodontid fishes mainly occurred because of a sharp decline in the percentage cover of branching corals *(Pocillopora* and *Acropora)* following cyclones and bleaching events. However, no clear trend was evident from the data obtained in this study to support the hypothesis that there is a correlation between butterflyfish abundance and depth within the zone of coral reef occurrence.

Previous studies indicated chaetodontid species regional specificity within the Persian Gulf. Carpenter *et al.* (1997) reported only three species in Kuwait and Qatar waters of the south-western Persian Gulf, and Al-Abdessalaam (1995) reported 12 species in UAE (United Arab Emirates) and Oman waters of the southern Persian Gulf. This study confirmed the presence of four chaetodontid species in Iranian waters of the northern Persian Gulf.

The results of the current study indicated that *C. melapterus* and *C. nigropunctatus* were always found associated with coral formations. Feeding preference may be the forcing factor for the observed relationship. Of the four Iranian species, *C. melapterus* and *C. nigropunctatus* are reported to feed exclusively or primarily on coral polyps (Lieske and Myers, 1994; Carpenter *et al.*, 1997). *C. vagabundus* is omnivorous, feeding on a varied diet of algae, coral polyps, crustaceans and worms (Cornic, 1987). This species was seen only rarely during the course of this study. For this reason, we cannot recommend *C. vagabundus* as a viable candidate indicator species. *H. acuminatus* is a planktivorous species, although it usually remains a few metres above coral (Cornic, 1987). Results of our study are consistent with this observation, and would indicate that *H. acuminatus* is likewise not a viable candidate indicator species.

Several studies (e.g. Chabanet *et al.*, 1997; Öhman *et al.*, 1998; Zekeria and Videler, 2000; Adjeroud *et al.*, 2002) suggested that the abundance of butterflyfish is positively influenced by the density of hard corals. This current study offers support for the conclusions of these earlier studies. However, the limited sample size in this study and recent coral bleaching perturbation of coral reefs in Kish Island and Ni-Band Bay are potential confounding factors in the less than absolute support for the indicator species hypothesis (Reese, 1981; Crosby and Reese, 1996).

Conversely, data from Larak Island, where the corals were in relatively good health with high species richness and abundance, a positive correlation between the abundance of butterflyfish and the density of living hard corals was observed. Data sets from individual sites and times probably had too small a sample size for significant correlations between *C. nigropunctatus* to be statistically evident. However, when all transects from all sites, times and depths were pooled, *C. nigropunctatus* was clearly correlated with abundance of coral.

Reese (1981) and Crosby and Reese (1996) have suggested that corallivore butterflyfish could be used as indicator species for changing conditions of coral reefs. Results of the current study indicate that *C. nigropunctatus* may be an excellent candidate for such an indicator species in Iranian waters of the northern Persian Gulf, but further studies are required to confirm this. We encourage more extensive surveys in the northern Persian Gulf to provide more convincing support for the use of *C. nigropunctatus* as an indicator of changing conditions in coral reefs.

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